

Quality Provision in Deregulated Industries: The Railtrack Problem

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This Draft: 09/06/2000

ABSTRACT: This paper studies a network provider's incentives to invest in infrastructure quality. In a simple but general framework, we investigate how various institutional settings affect investment incentives. We show that under reasonable assumptions on demand, investment incentives are smaller under vertical separation than under vertical integration. We consider two strategies for improving investment incentives under vertical separation. First, the introduction of competition for the market can sometimes improve incentives. Second, with non-linear access prices investment incentives under separation become identical to those under integration.

Keywords: investment incentives, networks, quality, railways, vertical externality.

JEL: D42, L22, L43, L92.

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We are grateful to Thomas Borek and seminar audiences at St. Gallen, Linz, Zurich and the Studienzentrum Gerzensee for helpful discussions.

1 Introduction

The privatization and deregulation of railways in Europe is taking up speed. Several European countries are gradually moving from the traditional state monopoly to private ownership structures and are attempting to implement various forms of competition. Legislators appear to be driven by the common view that monopoly structures remain acceptable solely with respect to the provision of infrastructure, whereas the provision of railway services should be subject to competition. The institutional changes resulting from this view have met with mixed support in the general public, to put it mildly. In particular, a widespread concern is that privatization leads to a deterioration of rail-services, brought about by a lack of incentives to invest in infrastructure. More specifically, vertical separation in the railway sector is often seen as the main culprit for insufficient investment into the improvement of network quality. The Economist (July 3, 1999, 67) echoes this view in its description of the British case:

“The promised investment of £27 billion [...] by Railtrack, which owns the track and the stations, is a sham — almost two-thirds of it is routine maintenance. Unless the incentives in the system change to make investment worthwhile, it will stay a sham.”

It is this claim of insufficient investment that we shall focus on in this paper. We analyze the effects of alternative institutional arrangements on the incentives to invest in network quality. Our analysis will, however, focus on different types of privatized industries, not on a comparison between privatized and state industries.

Such institutions differ widely across countries. For instance, competition for railway services can be coupled with various degrees of vertical integration. The approach taken in Great Britain is the most radical: the network is owned by a monopolist (Railtrack) who is not allowed to provide railway services. Railway services are supplied by independent train operating companies (TOCs). Hence, full vertical separation obtains.¹ At the other ex-

¹See Preston (1996) and the references therein for further details.

treme is the approach adopted in Switzerland, where network owners are free to provide railway services in addition to infrastructure. In this sense, full vertical integration applies in the Swiss case.² Other countries take intermediate approaches. In Germany, for example, the network provider DB Netz AG is formally separated from the (downstream) service providers. Nevertheless, these firms are allowed to belong to one holding for the time being (Lindemann and Oelschläger 1998).³

Apart from the extent to which network owners' downstream activities are tolerated, there are considerable differences with respect to network access for train operating companies. For example, in Great Britain, the right to run passenger trains on particular segments of the network is auctioned off by a franchising agency (Office of Passenger Rail Franchising, OPRAF). The successful bidder enjoys a local monopoly for a limited period of time, usually five to seven years. In addition, the franchisee has to pay access charges to the network provider Railtrack, which are negotiated between Railtrack and OPRAF (Preston 1996; Preston et al. 2000).⁴ In Germany and Switzerland, there are two different forms of getting access to particular segments of the network. The first is relevant for firms that win the competition for the provision of public railway services specified by local and national traffic authorities. Such firms are granted exclusive rights ("concessions") to provide public services on the designated network segments.⁵ The second concerns the providers of services which are not specified by traffic authorities. For these firms, the principle of open and non-discriminatory network access applies, which assures the right to run trains on designated parts of the network during specific time intervals, i.e. several different companies can—at least in principle—run trains on the same part of the network at different

²See Federal Department of the Environment, Transport, Energy and Communications (1996).

³See Van de Velde et al. (1999) for a recent survey of the reform in the railway industry.

⁴This is only true for passenger traffic; for freight transport, access rates result from negotiations between Railtrack and the train operators.

⁵Nevertheless, other firms can get non-discriminatory access to the designated segments as well, provided that they produce sufficiently differentiated products that do not directly compete with public services.

times.⁶

Finally, access tariffs can be determined in many ways. For example, they could be set freely by the network provider. However, since the provision of the network infrastructure is generally viewed as a natural monopoly, access tariffs are usually set or at least restricted by a regulatory authority.⁷ Tariffs also differ in the extent to which quality is rewarded by higher access rates. There is usually a small number of different quality categories, within which the access price is unaffected by network quality. In Germany, for example, there are six classes of railway lines, differing with respect to the speed for which they are suitable. Additional quality categories are not considered when determining access prices (Haase 1998, 463). In Switzerland, the track quality is a determinant of the markup of the access charge over the so called “normalized marginal cost”. This markup is defined by the regulatory authority and uniform throughout the country. Consequently, the relationship between network quality and access prices is highly imperfect, and higher quality is only partly rewarded by higher access prices for network owners. We shall explore the implications of these imperfect rewards for quality provision.

Another important issue is whether access prices are strictly linear in the amount of network access demanded by a train operator, or whether fixed components are used. In the countries mentioned above, various types of tariff systems have been adopted. In Great Britain, for instance, tariffs are non-linear and over 90% of Railtrack’s access revenues are generated by the fixed component (British Office of the Rail Regulator 1999 [ORR], 1.17). In Germany, the recently introduced “infracard” system allows train operating companies to opt for two-part access tariffs with a fixed component and a relatively low variable component rather than a linear tariff.⁸ In Switzer-

⁶See the Council Directive 91/440/EEC which describes the minimal standards for the reform of European railways. The Swiss reform largely adheres to these principles.

⁷See Laffont and Tirole (1996) for a non-technical review of the theory and practice of regulating access prices.

⁸The system has been introduced mainly because it is expected to have a positive effect on the number of trains provided by the transport operating companies (Knieps 1998). We shall argue in this paper that it has additional benefits in terms of generating investment incentives.

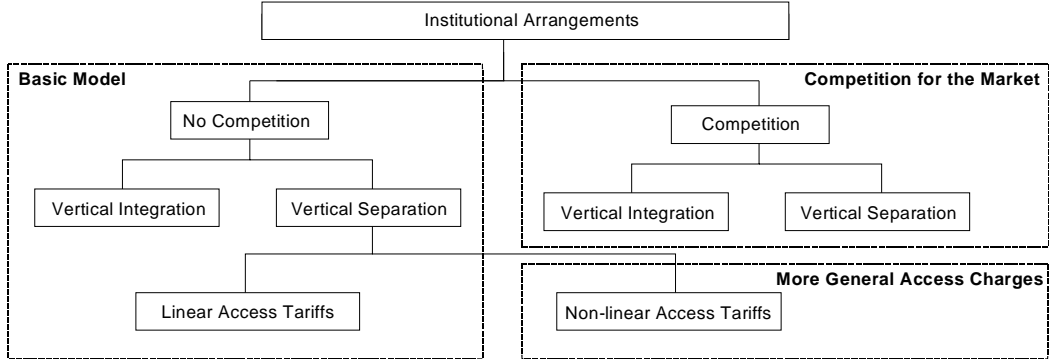


Figure 1: Various institutional arrangements

land, in turn, access tariffs are linear and regulated by the Federal Office of Transport.

To investigate the effects of these institutional differences, we model an industry in which an essential input (the *network infrastructure*) can be provided at various quality levels. High network quality is costly to provide, but increases the value of the industry's final output to the consumer,⁹ which we model as an outward shift of the demand schedule. Under vertical integration, a single firm decides on investment levels and output prices. Under vertical separation, the upstream firm (the *infrastructure owner*) decides on the quality of the network and sells the right to use the network to a downstream firm (the *train operating company*) that provides the final product for an access price that is determined according to the rules specified by the regulatory regime, but is independent of network quality. We shall analyze quality investment incentives generated under various institutional regimes and compare them with the social optimum (see Figure 1). Even though we develop our model in the context of the railway industry, we are confident that our analysis can be extended to other network industries where the quality of infrastructure plays an important role in determining demand, such as telecommunications, electricity, etc.

⁹For example, a high quality railway network will tend to reduce delays, allow for higher speed, shorten connection times and so forth.

The main results are as follows. First, incentives to provide quality are usually positive: even though access prices are assumed to be quality-independent, access revenues are not, as long as demand increases with quality. Second, incentives are generally smaller under vertical separation with linear access prices than under integration. This is partly due to the familiar vertical externality argument that investment has positive effects on downstream profits, which a separated upstream monopolist tends to ignore. However, we show that this is not the whole story, as a move from separation to integration also affects retail prices, which has subtle demand effects. Third, introducing downstream competition has ambiguous effects on quality. Compared to separation without downstream competition, a potential positive effect on quality arises because with downstream competition, retail prices are shown to be independent of quality, whereas in the case without competition, a price increase resulting from higher quality may reduce demand and thus make investment undesirable. However, we also show that for some demand functions, a countervailing effect might arise. Fourth, with non-linear access prices investment incentives of network owners are the same as in the integrated case, if the network owner can set the fixed components of access tariffs so as to appropriate the entire downstream profit.

The last two claims may appear somewhat disturbing given the British evidence that investment by the network owner Railtrack has been insufficient, even though downstream competition and non-linear access pricing are prominent characteristics of the institutional framework. As we will explain below, the difference stems from the fact that according to the British access price regime, the fixed component is essentially exogenous, whereas we allow for some flexibility.

While there is a large literature on the provision of quality by an unregulated monopoly, until recently little theoretical research was devoted to this issue in regulated environments (Laffont and Tirole 1993, 233). The recent deregulation and privatization process in many network industries, however, has led researchers to study investment incentives in vertically related markets. For instance, Bristow et al. (1998) provide a non-formal analysis of investment planning in Britain's privatized railway system. Economides (1999) studies the provision of quality for a composite good in vertically

related markets using the standard model of quality differentiation. More specifically, he explores the distortions in the provision of quality created by double marginalization. Our paper aims to add to this work by

- analyzing a more general reduced form model of vertically related network industries with infrastructure quality affecting consumer demand;
- incorporating various institutional settings into the formal analysis and comparing their relevant characteristics;
- identifying the driving forces determining investment patterns.

The plan of the paper is as follows. In a first step, we introduce our analytical framework (section 2). We then proceed to investigate the investment incentives under vertical integration and vertical separation with linear access prices and without competition (section 3). In section 4, we consider competition for the market and non-linear access prices as potential means of improving investment incentives. Finally, we summarize our results, discuss conclusions and outline the scope for further research (section 5).

2 The Basic Set-Up

This section develops a simple model of quality-enhancing investment in network industries, such as railways, to analyze the effects of various institutional regimes on investment behavior. Before discussing the model's characteristics, a note of caution is in place. We do not attempt to represent a specific institutional setting, such as the British or any other particular regulatory framework within our model. Instead, we shall employ the model to study the effects alternative institutional settings have on the incentives to invest in infrastructure quality.

2.1 General Assumptions

We consider an industry with a vertical structure. Suppose that in order to produce the final output (e.g. “total passenger kilometers”), the producer of this output needs access to an intermediate good (e.g. the right to use a

certain amount of track kilometers during a specified period of time). Assume for simplicity that to produce one unit of the industry's final output, one unit of the intermediate good is required. This intermediate good can be provided at various quality levels. Demand for the final good takes the form $D(p, \theta)$, where p is the price of the final output, and θ denotes the quality level. The demand function satisfies $D_p \equiv \partial D(\cdot)/\partial p < 0$ and $D_\theta \equiv \partial D(\cdot)/\partial \theta > 0$.¹⁰ Hence, a price increase reduces the demand for the final good, and a quality increase results in an outward shift of the demand schedule.¹¹ Providing quality is costly, which is captured in a strictly increasing cost function $K(\theta)$. In addition, there is a fixed cost F of running the network. For notational simplicity, we abstract from variable costs of running the network.

The production of railway services is modeled in two stages as follows:

- stage 1: The quality level θ of the network infrastructure is determined, either by a vertically integrated monopolist M or a separated (“upstream”) network operator U .
- stage 2: The integrated monopolist M or a (“downstream”) service provider D sets the price for railway services.

For vertical integration, the network owner is thus facing an optimization problem, whereas in the case of vertical separation, firms D and U play a simple sequential game. We now derive the relevant profit functions that will later be used to determine the incentives to invest in quality.

2.2 Example 1: Vertical Integration

Assume first that both the railway network and the railway services are provided by the same company M . In particular, M acts as an integrated monopolist on the final good market and is not subject to price regulation.

¹⁰The notational convention that subscripts denote partial derivatives is used throughout the paper.

¹¹We abstract from other aspects of output heterogeneity, such as the fact that some rail services are provided on different lines, at different times of day, and for different types of costumers (passenger or freight services).

Hence, the integrated firm's profit function is

$$\Pi^I(p, \theta) = pD(p, \theta) - K(\theta) - F.$$

Optimal behavior by the monopolist requires the maximization of profits with respect to p and θ . Suppose a unique solution $p^I(\theta)$ for the pricing problem under vertical integration exists for every θ .¹² Then the integrated firm's profit function can be written as a function of θ , i.e.

$$\Pi^I(p^I(\theta), \theta) = p^I(\theta)D(p^I(\theta), \theta) - K(\theta) - F. \quad (1)$$

We now turn to the case of vertical separation.

2.3 Example 2: Vertical Separation with Linear Access Prices and without Competition

Suppose now that the industry is served by a chain of monopolies. This is an extreme way to model a vertically separated industry. In most real-world examples, there is some degree of downstream competition, at least potentially. We use the downstream monopoly as a benchmark; later sections will explore the implications of introducing competition. The upstream firm U takes investment decisions and provides the network to a downstream firm D , which provides a unit of the final good at price p . Again, we are assuming that the price for the final good is not regulated. For the time being, we confine ourselves to access pricing schedules that are linear with respect to the quantity demanded by the downstream firm.¹³ More specifically, for each unit of network access, D pays an access charge $a > 0$ to U . To model the idea that access charges usually do not fully reflect network quality, we assume that the regulator sets a completely independent of quality, and we

¹²One way to ensure the existence of a unique solution would be to suppose that there is a price level at which the first-order condition $\Pi_p^I = 0$ holds, and that, in addition, Π^I is concave in p . Our arguments apply more generally, however, and we shall therefore not explicitly demand that these conditions hold.

¹³Non-linear access tariffs will be discussed in section 3.3.

explore whether alternative mechanisms exist to induce quality provision.¹⁴ Further, we assume that the upstream monopolist is able to break even, i.e. $\exists \theta$ such that $\Pi^U \equiv aD(p, \theta) - K(\theta) - F \geq 0$. Except stated otherwise, a is determined by the regulator.

Consider the *downstream firm's* behavior first. Given θ and a , the separated downstream firm D chooses p so as to maximize its profit

$$\Pi^D(p, \theta) = [p - a]D(p, \theta). \quad (2)$$

Assuming that there is a unique retail monopoly price $p^R(a, \theta)$ solving this problem, the *upstream firm* U chooses θ so as to maximize

$$\Pi^U(a, \theta) = a[D(p^R(a, \theta), \theta)] - K(\theta) - F. \quad (3)$$

Total industry profits $\Pi^D + \Pi^U$ under separation are then

$$\Pi^T \equiv \Pi^D + \Pi^U = p^R(a, \theta)D(p^R(a, \theta), \theta) - K(\theta) - F. \quad (4)$$

2.4 The General Form of Profit Functions

Let us compare the profit functions of the firms taking the quality decision under vertical integration and separation ((1) and (3), respectively). Observe that these profit functions have the common form

$$\Pi = p^U(\theta)D(p^R(\theta), \theta) - K(\theta) - F, \quad (5)$$

where Π denotes the relevant profits, $p^R(\theta)$ is the price paid by downstream costumers for the provision of the final good (the ‘retail price’) and $p^U(\theta)$ is the price per unit of demand obtained by the firm taking the quality decision. More specifically, $p^U(\theta) = p^R(\theta) = p^I(\theta)$ under vertical integration; under separation, however, $p^U(\theta) = a$ and $p^R(\theta) = p^R(a, \theta)$. The general structure of profits represented by (5) is robust to all institutional changes

¹⁴It is straightforward to show that by using access charges which respond according to network quality, arbitrary levels of quality could be induced. The practical applicability of such a concept, however, is limited by considerable monitoring and enforcement problems.

considered in this paper.

On a general level, the marginal incentives to invest in quality are thus easily determined. Defining $\widehat{D}(\theta) \equiv D(p^R(\theta), \theta)$, and differentiating the revenue function $\pi = p^U \widehat{D}(\theta)$ with respect to quality yields the investment incentives¹⁵

$$\pi_\theta = p^U(\theta) \widehat{D}_\theta + p_\theta^U \widehat{D}(\theta). \quad (6)$$

Applying straightforward calculations, we obtain

$$\widehat{D}_\theta = D_p \cdot p_\theta^R + D_\theta. \quad (7)$$

Inserting this into (6) and rearranging terms yields

$$\pi_\theta = \underbrace{p^U D_p \cdot p_\theta^R + p_\theta^U D}_{\substack{\text{price-mediated} \\ \text{effect}}} + \underbrace{p^U D_\theta}_{\substack{\text{direct} \\ \text{effect}}}. \quad (8)$$

Equation (8) shows more explicitly how a marginal quality increase affects the relevant profits. There is a *direct effect* of a quality increase which is generally positive, and a *price-mediated effect* with an ambiguous sign. We will show in section 3.2 that the sign of the price-mediated effect depends on the type of quality-enhancing investment considered.

3 Comparison of Institutional Arrangements

We now use the framework developed above to compare investment incentives under various institutional regimes. We start with the comparison of the two regimes already introduced, vertical integration and vertical separation with linear prices and without downstream competition. Section 3.1 briefly reviews a simple comparative statics result that we shall often use. Section

¹⁵Throughout the paper, Π indicates profit functions, whereas π denotes revenue functions. Note that it is enough to consider revenue functions to compare investment incentives for different institutions, since the cost function $K(\theta)$ is not affected by institutions.

3.2 provides an auxiliary result about the effects of quality on downstream prices and quantities. In section 3.3, we compare investment incentives; in section 3.4, we briefly touch upon welfare considerations.

3.1 Preliminaries on Comparative Statics

For the comparison of investment levels in different institutional regimes, we use the following simple result, which is a direct implication of Milgrom and Roberts (1990, Th. 5).

Lemma 1 *Consider the following maximization problem:*

$\max_x f(x, \alpha)$ s.t. $x \in \mathbb{R}^+$, where $\alpha \in \{\alpha_1, \alpha_2\}$ and $f(x, \alpha)$ is a differentiable function such that

$$\frac{\partial f}{\partial x}(x, \alpha_1) > \frac{\partial f}{\partial x}(x, \alpha_2) \text{ for all } x.$$

Suppose a unique maximum $x^(\alpha)$ exists for each $\alpha \in \{\alpha_1, \alpha_2\}$. Then*

$$x^*(\alpha_1) > x^*(\alpha_2).^{16}$$

Intuitively, lemma 1 simply means that if the value of the derivative is higher for arbitrary values of x , the incentive to increase x is higher. In terms of the investment problem considered here, this result implies that the higher the value π_θ of the profit function's derivative with respect to quality, the higher is the incentive to invest in quality.

3.2 The Type of Investment

As indicated above, much of the following will depend on the nature of investment, specifically on how the quality improvement affects the equilibrium retail price p^R and the demand. One might expect that higher quality will unequivocally lead to higher prices and higher output. For simple demand functions, such as $D(p, \theta) = 1 - p + \theta$, this is indeed the case.¹⁷ In general, however, it is possible that either price or output decrease as a result of a

¹⁶Note that the result does not require concavity of $f(\cdot)$ in x , just existence of a unique global maximizer. In fact, the result by Milgrom and Roberts has a more general formulation for set-valued optima and non-differentiable functions.

¹⁷Simple calculations show that $\frac{dp}{d\theta} = \frac{1}{2}$ and $\frac{d\bar{D}}{d\theta} = \frac{1}{2}$.

quality increase. For simplicity, suppose that the following natural assumption is satisfied:

- (A 1) The regulator sets the access price always lower than the retail price,
i.e. $p^R > a > 0$.

With this assumption, we obtain the following result.

Lemma 2 (*Types of investment*)

Assume that the downstream firm's profit function π^D is concave.

- (i) Suppose that $D_{p\theta}$ is positive and sufficiently large. Then $p_\theta^R > 0$ and $\hat{D}_\theta < 0$ (**Regime 1**).
- (ii) Suppose that the absolute value of $D_{p\theta}$ is sufficiently small. Then $p_\theta^R > 0$ and $\hat{D}_\theta > 0$ (**Regime 2**).
- (iii) Suppose that $D_{p\theta}$ is negative with sufficiently large absolute value. Then $p_\theta^R < 0$ and $\hat{D}_\theta > 0$ (**Regime 3**).

Proof. According to lemma 1, $\text{sign}(p_\theta^R) > (<) 0$ if

$$\pi_{p\theta}^D = [p^R - a]D_{p\theta} + D_\theta > (<) 0,$$

$D_{p\theta} > (<) -\frac{D_\theta}{p^R - a}$. In equilibrium, p_θ^R is given by

$$\frac{dp^R}{d\theta} = -\frac{\pi_{p\theta}^D}{\pi_{pp}^D} = -\frac{[p^R - a]D_{p\theta} + D_\theta}{2D_p + [p^R - a]D_{pp}}.$$

Substituting p_θ^R into $\hat{D}_\theta = D_p \cdot p_\theta^R + D_\theta$ and transforming yields $\text{sign}(\hat{D}_\theta) > (<) 0$ if

$$D_{p\theta} < (>) \frac{D_\theta}{D_p} \left(\frac{D_p}{p^R - a} + D_{pp} \right).$$

The respective statements on the three different regimes now follow immediately from $D_\theta > 0$, $D_p < 0$ and $D_{pp} < 0$. ■

To understand this result, one needs to clarify what lies behind the sign and absolute value of $D_{p\theta}$. Intuitively, a positive value of $D_{p\theta}$ stands for cases

where the demand-enhancing effect of quality is particularly strong for high prices. This could be so if the investment is particularly valuable to customers with a high willingness to pay for rail services (Regime 1). The railway company would then increase prices after the investment, thereby attracting high rents from costumers with high willingness to pay while possibly loosing total demand. Similarly, a negative value of $D_{p\theta}$ will arise when quality is particularly valuable for customers with a low valuation for rail services (Regime 3). When we do not expect any important relation between prices and the demand-enhancing effect of quality, it is reasonable to assume that $D_{p\theta} = 0$, so that we are in Regime 2.¹⁸

For an explicit example where a quality increase leads to a demand reduction, consider a somewhat extreme case. Suppose θ takes on two possible values $\theta = \{0, 1\}$. Suppose the demand function is given by

$$D(p, \theta) = \begin{cases} 1 - p, & \text{for } p > \frac{1+a}{2} - \varepsilon \\ 1 - p + \theta, & \text{for } p \leq \frac{1+a}{2} - \varepsilon \end{cases}.$$

Then, for sufficiently small ε , the resulting price will be $p^R(a, \theta) = \frac{1+a}{2}$ for $\theta = 0$ and $p^R(a, \theta) = \frac{1+a}{2} - \varepsilon$ for $\theta = 1$. Thus, the price decreases as a result of the quality increase. This example may seem a little contrived as $D(p, \theta)$ is not continually differentiable and θ affects demand only below the threshold level ($p \leq \frac{1+a}{2} - \varepsilon$). Nevertheless, it is clearly possible to approximate this demand function with a continually differentiable function where $D_\theta > 0$ everywhere, such that the same conclusion holds. It is essential, however, that the quality effect on demand is concentrated at prices below the low-quality monopoly price.

3.3 Comparison of Investment Incentives

We now proceed to the analysis of investment incentives under various institutional arrangements, applying the analytical framework developed in the last two sections. To begin with, recall that $p^U = p^R = p^I(\theta)$ in the case

¹⁸Note that from the condition $\pi_{p\theta}^D > 0$, the lower bound for Regime 2 must be $D_{p\theta} = -\frac{D_\theta}{p^R - a}$.

of vertical integration, and demand is evaluated at $(p^I(\theta), \theta)$. From (8), the investment incentive is thus

$$\pi_\theta^I = p^I(\theta) \cdot D_p(p^I(\theta), \theta) \cdot p_\theta^I + p_\theta^I \cdot D(p^I(\theta), \theta) + p^I(\theta) \cdot D_\theta(p^I(\theta), \theta). \quad (9)$$

Assuming that for each quality the price is chosen so as to satisfy the first-order condition

$$\pi_p^I = D(p^I(\theta), \theta) + p^I(\theta) \cdot D_p(p^I(\theta), \theta) = 0,$$

equation (9) simplifies to

$$\pi_\theta^I = p^I(\theta) D_\theta(p^I(\theta), \theta). \quad (10)$$

Compare this result with the more general formulation of equation (8). Inspection of (10) shows that π_θ^I is simply the *direct effect* of a quality increase. That is, the *price-mediated effect* of a quality increase on profits is zero at the profit maximum. The intuition of this result is straightforward. If retail prices are optimally set, a marginal quality increase does not affect prices.¹⁹

Under vertical separation, the relevant prices are $p^R = p^R(a, \theta)$ and $p^U = a$. The investment incentive is

$$\pi_\theta^U = a \widehat{D}_\theta = a [D_p(p^R(a, \theta), \theta) \cdot p_\theta^R + D_\theta(p^R(a, \theta), \theta)]. \quad (11)$$

The next result follows immediately from lemma 2.

Proposition 1 *In Regime 2 and 3, investment incentives under vertical separation are positive as long as (A 1) holds.*

Even though the result is very simple, it is informative with respect to the claim that separated network monopolists face literally no incentives to invest in quality if access charges are insensitive to quality levels. Proposition 1 shows that such a stark claim is false, because even if access charges are

¹⁹This result is of course an application of the envelope theorem.

insensitive to quality, the upstream monopolist is rewarded for higher quality by higher access revenues, provided that quality is in fact demand enhancing.

To be sure, the argument depends essentially on the assumption that the access price is greater than marginal cost (i.e. $a > 0$, as we have normalized marginal cost to zero): otherwise, as ORR (1999, 4.1) notes

“if the variable access charge in the track access agreements are based on the incremental costing in the short term from increased use, this should mean that Railtrack is broadly indifferent to the utilization of the network”.

We now proceed to analyze under which conditions the weaker claim that innovation incentives are stronger under vertical integration than under separation is correct, i.e. $\pi_\theta^I > \pi_\theta^U$. To this end, we apply equation (8) to both cases. Consider the *price-mediated effect*. Under vertical integration, this effect was shown to be zero. Under separation, the sign of the price-mediated effect ($aD_p \cdot p_\theta^R$) is generally negative, as increasing prices reduces demand, except in Regime 3 (see lemma 2).

Now, consider the direct effect. Note that $p^U = p^R$ under vertical integration. Using (A 1), we thus conclude that p^U is larger under vertical integration than under separation. The direct effect $p^U D_\theta$ of quality on profits is thus larger in the former case, unless the demand effect under separation is much higher than under integration, that is, unless $D_\theta(p^R(a, \theta), \theta)$ is much higher than $D_\theta(p^I(\theta), \theta)$. To see how these demand effects compare, some additional observations are helpful.

Lemma 3 $p^I(\theta) = p^R(0, \theta)$.

This statement is true because both prices correspond to monopoly prices of firms serving the downstream market with zero marginal costs. Hence, we can treat vertical integration as the boundary case of vertical separation with $a = 0$. We can therefore use the unified notation $p^R(a, \theta)$ to include both the retail price under separation if $a > 0$ and the price under integration, $p^R(0, \theta) = p^I(\theta)$ if $a = 0$.

The next observation follows immediately from total differentiation of the first-order condition for equilibrium retail pricing. It is familiar from

the well-known double mark-up argument that in a chain of monopolies the resulting price of the downstream firm is higher than what the integrated firm would charge.²⁰

Lemma 4 $p^R(a, \theta)$ is strictly increasing in a . In particular, $p^R(a, \theta) > p^I(\theta)$ for arbitrary positive access prices a .

The intuition is straightforward: Increasing the access tariff a is equivalent to increasing the marginal cost of the downstream firm. Applying lemma 3 and 4 yields the conclusion that the direct demand effect $D_\theta(p(\theta), \theta)$ of a quality increase can only be larger under vertical separation if $D_{p\theta}$ is positive.

Summing up, we have that (i) the price-mediated effect tends to lead to higher investment incentives in the case of integration, unless we are in Regime 3, that is, unless $D_{p\theta}$ is negative with high absolute value, and (ii) the direct effect reinforces the price-mediated effect unless $D_{p\theta}$ is very positive. The following proposition summarizes these countervailing effects and presents the net results for the three Regimes considered above.

Proposition 2 (*Integration vs. Separation*) Suppose (A 1) holds.

- (i) In Regime 1, the incentive to invest in quality is stronger under vertical integration than under separation, i.e. $\pi_\theta(p(0, \theta), \theta) > \pi_\theta(p^R(a, \theta), \theta)$ for $a > 0$.
- (ii) In Regime 2, the incentive to invest in quality is stronger under vertical integration than under separation, except possibly if $D_{p\theta}$ is positive and sufficiently large.
- (iii) In Regime 3, the incentive to invest in quality may be stronger under vertical separation than under integration.

Proof. Using (10) and (11), integration yields stronger innovation incentives than separation if

$$p^I(\theta)D_\theta(p^I(\theta), \theta) > a\hat{D}_\theta = a [D_p(p^R(a, \theta), \theta) \cdot p_\theta^R + D_\theta(p^R(a, \theta), \theta)] .$$

²⁰Note that lemma 4 does not reflect a double mark-up in a strict sense, since the access charge a is not chosen by the upstream firm but exogenously set by the regulator.

- (i) For Regime 1, lemma 1 implies $\widehat{D}_\theta < 0$. Hence, the right-hand side of this inequality is negative and the claim immediately follows.
- (ii) For Regime 2, lemma 1 gives $D_p(p^R(a, \theta), \theta) \cdot p_\theta^R < 0$. Hence, it suffices to show that, for $a > 0$,

$$p^I(\theta)D_\theta(p^I(\theta), \theta) > aD_\theta(p^R(a, \theta), \theta).$$

As $p^I(\theta) > a$ by (A 1), this condition clearly holds if $D_\theta(p^I(\theta), \theta) > D_\theta(p^R(a, \theta), \theta)$. By lemma 1, integration thus yields higher incentives provided $D_{p\theta} \leq 0$ or at least not very high.

- (iii) In Regime 3, the very negative values of $D_{p\theta}$ lead to $p_\theta^R(a, \theta) < 0$, which gives a positive first term in brackets that is absent under integration. At the same time, D_θ is higher in the integration case than in the separation case. It is unclear which of these effects dominates. ■

One might ask why it is not always the case that investment incentives are larger under integration than under separation. More specifically, one could argue—following the well-known vertical externality rationale—that an economic agent will underinvest if he is not able to fully appropriate the returns on investment (see e.g. Hart 1995). In fact, it is easy to show that such a vertical externality indeed exists, i.e. increasing upstream quality increases downstream profits:

$$\Pi_\theta^D = p_\theta^R \cdot \widehat{D}(\theta) + [p^R(a, \theta) - a] \widehat{D}_\theta(\theta) > 0. \quad (12)$$

This statement is true because the downstream firm can always leave the price unchanged as a reaction to a quality increase, yielding minimal additional profits of $[p^R(a, \theta) - a] \widehat{D}_\theta$. Hence, an agent who maximizes total industry profits $p^R(a, \theta) \cdot D(p^R(a, \theta), \theta) - K(\theta) - F$ rather than upstream profits would choose a higher investment level. However, proposition 2 demonstrates that this line of argument is too simple in the context considered here.

Integration does not only mean that the effect of quality on downstream profits is considered by the investing party, which, to repeat, would tend to increase investment incentives. It also means that downstream prices fall from $p^R(a, \theta)$ to $p^I(\theta)$, i.e. the double mark-up is eliminated: to recall, the ob-

Table 1: Summary of results

	(I)	(II)
Institutional Arrangements	$\pi^T - \pi^U = \pi^D$	$\pi^I - \pi^T$
VS/LP	$p^R(a, \theta)D(p^R(a, \theta), \theta)$ $-aD(p^R(a, \theta), \theta)$	$p^R(0, \theta)D(p^R(0, \theta), \theta)$ $-p^R(a, \theta)D(p^R(a, \theta), \theta)$
VS/DC	$aD(a, \theta)$ $-aD(a, \theta)$ $= 0$	$p^R(0, \theta)D(p^R(0, \theta), \theta)$ $-aD(a, \theta)$
VS/NLAT	$p^R(0, \theta)D(p^R(0, \theta), \theta)$ $-p^R(0, \theta)D(p^R(0, \theta), \theta)$ $= 0$	$p^R(0, \theta)D(p^R(0, \theta), \theta)$ $-p^R(0, \theta)D(p^R(0, \theta), \theta)$ $= 0$
legend:		
VS/LP: Vertical Separation/Linear Prices		
VS/DC: Vertical Separation/Downstream Competition		
VS/NLAT: Vertical Separation/Nonrestricted Non-linear Access Tariffs		

jective under integration is $p^I(\theta) \cdot D(p^I(\theta), \theta) - K(\theta) - F$. This in turn implies that the vertically separated upstream firm might, in principle, have higher incentives to invest than an integrated firm if the quality increase enhances demand more strongly for higher retail prices ($D_{p\theta} > 0$)—but this effect must be sufficiently strong to outweigh the standard vertical externality.

The first row of Table 1 summarizes this idea. The difference between the revenue of a vertically separated upstream firm π^U and an integrated firm π^I is the sum of $\pi^T - \pi^U = \pi^D$ (column I) and $\pi^I - \pi^T$ (column II), where π^T denotes total industry revenue under vertical separation. The derivative of the first expression ($\pi_\theta^D > 0$) reflects the familiar vertical externality of quality enhancement on downstream revenue. The derivative of the second expression ($\partial(\pi^I - \pi^T)/\partial\theta$) reflects the mark-up effect resulting from the fact that prices are usually not the same in the separated and integrated case.

3.4 The Social Welfare Benchmark

Let us compare the investment incentives derived under vertical integration and separation with those in the welfare optimum. We briefly adapt a familiar underinvestment result for monopolistic firms derived by Spence (1975) to our setting. Consider the case of vertical integration. Let

$$S = \int_{p^R}^{\infty} D(\tilde{p}, \theta) d\tilde{p} \quad (13)$$

be the consumer surplus, and

$$\Pi^I = p^R D(p^R, \theta) - K(\theta) - F \quad (14)$$

the integrated monopolist's profit for any given price p^R . Total surplus is then $W = S + \Pi^I$. Hence, the following relation obtains:

$$W_\theta = S_\theta + \Pi_\theta^I = \int_{p^R}^{\infty} D_\theta(\tilde{p}, \theta) d\tilde{p} + \Pi_\theta^I > \Pi_\theta^I. \quad (15)$$

Thus, for $\Pi_\theta^I = 0$, we must have $W_\theta > 0$. In other words, at any given price p^R , the vertically integrated monopolist underprovides quality relative to the social optimum.

Hence, in those cases where vertically separated firms provide less quality than integrated firms, they also provide less quality than the social optimum.

4 Means to Improve Investment Incentives

4.1 Competition for the Market/Linear Access Prices

We now analyze the effects of competition on investment incentives. Demsetz (1968) pointed out that in the case of a natural monopoly—that is, competition *within* the market leads to cost inefficiency—competition *for* the market in the form of franchise bidding can be introduced in order to achieve the social welfare optimum, constrained by the requirement that firms break even. The franchise is awarded to the successful bidder. Under this type of auction, a bid takes the form of a binding price that the bidding firm will charge for

service if it wins the auction. The firm that offers the lowest price becomes the franchisee. For this kind of setting, it is often argued that if quality is a choice variable and providing quality is costly, franchise bidding over the price alone will drive down both price and quality (Viscusi et al. 1995, 421).

In principle, this problem can be circumvented by imposing quality thresholds or holding multidimensional auctions where bids have both a price and a quality dimension. The incentives to invest in quality then depend on the specific design of the competitive process. Readers interested in further details are referred to Cripps and Ireland (1994) for the analysis of quality thresholds and to Branco (1997) for the analysis of multidimensional auctions. In the spirit of the analysis so far, we shall instead ask whether incentives to provide quality can be given indirectly, if demand depends on quality.

To this end, we discuss a case that is more closely related to real-world examples, for instance to the present practice in Great Britain: we assume that there is vertical separation with a designated private network owner such as the British monopolist Railtrack. The downstream monopoly, however, is auctioned off.²¹

Assume there is a pool of n firms with identical costs participating in the franchise bidding process for the separated downstream monopoly. Before considering a Demsetz-type auction of the franchise for the downstream market, it is useful to conduct a simple thought experiment to see which form of competition might be suitable to improve incentives to invest in quality.

Suppose that firms bid a franchise fee for the exclusive right to serve the market. Intuition suggests that the highest willingness to pay is given by the monopoly profit that can be earned on this market. Therefore, the winner of the auction will set the monopoly retail price $p^R(a, \theta)$ to break even. For any given access price a , the incentive to invest in quality is thus just the same as under vertical separation without competition. This type of a standard first-price auction is thus ill suited to improve investment incentives.

Now, consider a simple Demsetz-type auction.²² Assume the course of events can be summarized as follows.

²¹It can be shown that there are also positive incentives to provide quality if the entire industry is auctioned off to generate an integrated monopoly.

²²The extension to heterogeneous firms is straightforward.

- stage 1: Given the access charge a , the upstream firm U determines investment in quality θ .
- stage 2: Observing the access charge a and the quality level θ set by the upstream firm, each competitor i for the downstream monopoly bids a price p^i at which they will provide railway services. The firm with the lowest bid \underline{p} wins the auction and pays the price of the second-lowest bid.

We apply the solution concept of subgame perfect equilibrium. In the equilibrium of the second stage, the price \underline{p} for railway services is driven down to average cost which is equal to the exogenously set access charge a , i.e. $p^R = \underline{p} = a$. Anticipating this result, the upstream firm U chooses quality so as to maximize

$$\Pi^U(a, \theta) = aD(a, \theta) - K(\theta) - F.$$

in the first stage of the game. The investment incentive is thus

$$\pi_\theta^U(a, \theta) = aD_\theta(a, \theta). \quad (16)$$

Observe that due to the fact that the consumer price is driven down to a independent of the quality level, there is no price-mediated effect anymore.

Let us compare the investment incentives of an integrated monopolist with those of a monopolist facing a separated downstream franchisee (see (10) and (16), respectively, and Table 1, row 2). Observe that in both cases the *price-mediated effect* is absent. However, there is a difference with respect to the *direct effect*. Since $p^I(\theta) > a$, any quality induced demand increase has a stronger effect on the integrated than on the vertically separated upstream firm's profits. Yet, competition for the downstream market might overcompensate this disadvantage if the quality effect on demand is much stronger for lower prices, i.e. $D_\theta(a, \theta) \gg D_\theta(p^I(\theta), \theta)$, which would require $D_{p\theta} < 0$. The next proposition summarizes the result.

Proposition 3 (*Separation with competition vs. Integration without competition*) Suppose (A 1) holds. Then the incentive to invest in

quality is weaker under vertical separation with competition than under vertical integration without competition, unless $D_{p\theta} < 0$.²³

Hence, in general competition does not solve the underinvestment problem; but does it alleviate it? To answer this question, consider the investment incentives in a vertically separated industry with and without competition for the downstream market (see (16) and (11), respectively). Observe that in both cases, the price p^U collected by the upstream firm is the same, namely a , which is set by the regulator and independent of quality by assumption. This has important consequences in the case of competition for the market: Since consumer prices are driven down to $p^R = a$, the downstream firm is restricted to zero profits. Consequently, there is no vertical externality attached to the upstream firm's investment behavior: higher investment does not increase downstream profits. At first glance, this might lead one to conclude that investment incentives are higher with competition. However, this is not always true. The demand effect of quality is $D_\theta(a, \theta)$ with competition, the corresponding term is $\widehat{D}_\theta(p^R(a, \theta), \theta) = D_p(p^R(a, \theta), \theta) \cdot p_\theta^R + D_\theta(p^R(a, \theta), \theta)$ in the absence of competition. In Regimes 1 and 2, i.e. for $D_{p\theta}$ positive or not too negative, there is a negative price-mediated effect of quality when there is no competition; this negative effect does not exist when there is competition. On the other hand, the positive direct effect is higher when there is no competition ($D_\theta(p^R(a, \theta), \theta) > D_\theta(a, \theta)$) if $D_{p\theta} > 0$. Again, our next theorem summarizes the outcomes under the three Regimes.

Proposition 4 (*Separation with competition vs. Separation without competition*) Suppose (A 1) holds.

- (i) In Regime 1, ($p_\theta^R > 0, \widehat{D}_\theta < 0$), the incentive to invest in quality under vertical separation is stronger with competition than without competition.
- (ii) In Regime 2, ($p_\theta^R > 0, \widehat{D}_\theta > 0$), the incentive to invest in quality under vertical separation is stronger with competition than without competition, except possibly if $D_{p\theta}$ is positive and sufficiently large.

²³The result can be made slightly more precise. As the incentives in both cases are just $pD_\theta(p, \theta)$ evaluated at different values of p , integration yields higher incentives if $pD_{\theta p} + D_\theta$ is everywhere negative.

(iii) In Regime 3, ($p_\theta^R < 0, \hat{D}_\theta > 0$), the incentive to invest in quality under vertical separation may be weaker with competition than without competition.

Proof. Using (11) and (16), the investment incentive is stronger with competition than without if

$$D_\theta(a, \theta) > \hat{D}_\theta \equiv D_p(p^R(a, \theta), \theta) \cdot p_\theta^R + D_\theta(p^R(a, \theta), \theta).$$

(i) In Regime 1, $D_{p\theta}$ is positive and sufficiently large so that $\hat{D}_\theta < 0$. Since $D_\theta > 0$ by definition, the claim follows immediately.

(ii) In Regime 2, $D_{p\theta}$ is sufficiently small in absolute value so that $p_\theta^R > 0$, and the indirect effect $D_p(p^R(a, \theta), \theta) \cdot p_\theta^R$ is negative. Incentives are thus higher with competition if $D_\theta(a, \theta) \geq D_\theta(p^R(a, \theta), \theta)$ or at least not too negative due to $p^R(a, \theta) > a$. This is true as long as $D_{p\theta}$ is negative or at least not too positive. Hence, the result follows.

(iii) In Regime 3, $D_{p\theta}$ is negative with sufficiently large absolute value so that $\hat{D}_\theta > 0$. Under these circumstances, $D_\theta(a, \theta)$ may be smaller than \hat{D}_θ , and hence it remains unclear whether the claim is satisfied. ■

Thus, in spite of the fact that downstream competition eliminates the price-mediated effect of quality improvements, the overall effect of competition on incentives is ambiguous.

4.2 Non-linear Access Prices/No Competition

We now turn to the analysis of more general forms of access prices. Note that in the following we always refer to institutional settings without competition. So far, we assumed the access charge per unit of demand to be independent of the quantity of access demanded by the downstream firm. In the real-world, non-linear access tariffs are observed. We shall show to which extent they can solve the underinvestment problem under vertical separation.

4.2.1 Unrestricted Two-part Access Tariffs

Assume that instead of a linear access price a , the upstream monopoly charges a two-part tariff of the form $T(\tilde{a}) = A + \tilde{a}D(\cdot)$; that is, the down-

stream monopolist pays a fixed premium A plus a variable access charge \tilde{a} for the access to the intermediate good. In addition, suppose that the upstream firm chooses \tilde{a} , A and θ . More specifically, assume that the upstream firm is free to choose a linear or non-linear pricing schedule and that there are no regulatory restrictions imposed on the level of the access tariff components a or A . Finally, suppose both the upstream and the downstream firm are perfectly informed.

In this setting, we can derive the following result (see Table 1, row 3, also).

Proposition 5 (*Two-part Access Tariffs*) *Suppose that the industry is vertically separated and that the network monopolist is allowed to set an arbitrary two-part tariff $T(\tilde{a}) = A + \tilde{a}D(\cdot)$. Then*

- (i) *the variable access charge will be chosen as $\tilde{a} = 0$;*
- (ii) *the incentive to invest in quality is the same as under vertical integration;*
- (iii) *the fixed premium is chosen as $A = \Pi^I(p^I(\theta), \theta)$.*

The intuition of this result is straightforward. The upstream monopolist maximizes aggregate profits because it is able to completely extract the profit of the downstream firm. Hence, it enjoys the full benefits of its investment in higher quality and thus has the same incentive to invest as a vertically integrated firm.²⁴ In principle, the same outcome could be achieved by (i) demanding that the downstream monopolist should enter the market and (ii) imposing zero access prices. This would, however, require subsidies for the monopolist to break even—with the familiar distortions.

More precisely, the argument goes as follows. The downstream firm will only produce if it realizes a non-negative profit, that is, if

$$\Pi^D(p, \tilde{a}, A) = [p^R(\tilde{a}, \theta) - \tilde{a}]D(p^R(\tilde{a}, \theta), \theta) - A \geq 0. \quad (17)$$

By setting $A = [p^R(\tilde{a}, \theta) - \tilde{a}]D(p^R(\tilde{a}, \theta), \theta)$, the upstream firm is able to fully extract the downstream firm's profit irrespective of the value of the variable

²⁴Thus, the fixed premium works essentially like a franchise fee payable to the upstream firm for the right to serve the downstream market.

access charge \tilde{a} . Hence, the problem of the upstream firm simply consists of setting θ and \tilde{a} so as to maximize joint profits

$$\Pi^T \equiv \Pi^D + \Pi^U = p^R(\tilde{a}, \theta) D(p^R(\tilde{a}, \theta)) - K(\theta) - F.$$

Thus, for any given θ its objective is to set \tilde{a} so as to maximize the monopoly profit with marginal cost \tilde{a} . As this profit is decreasing in \tilde{a} , U will set the variable component of the access tariff equal to zero no matter what the quality level θ is. With $\tilde{a} = 0$, the investment incentive under a non-restricted two-part tariff becomes

$$\pi_\theta^T = p^R(0, \theta) D_\theta(p^R(0, \theta), \theta) = \pi_\theta^I. \quad (18)$$

Because $p^R(0, \theta) = p^I(\theta)$ by lemma 3, the upstream firm behaves exactly like an integrated monopolist (see (10)), that is, as in the case of competition for the downstream market, the vertical externality is completely eliminated. There is, however, an important difference to franchise bidding for the downstream monopoly. In contrast to the introduction of competition, the introduction of unrestricted two-part access tariffs not only eliminates the vertical externality, but also the ‘mark-up distortion’ introduced by the vertical separation of the industry (relative to integration). This result is due to the fact that in such a setting, the upstream firm can also set the variable access tariff—which is exogenous under franchise bidding for the downstream monopoly—and thereby virtually replicate the behavior of an integrated monopolist.²⁵

On the face of it, this result stands in marked contrast to recent claims that the apparent underinvestment of Railtrack is caused by the high fixed element in Railtrack’s revenue and the lack of a “volume incentive” which results from the variable component being close to marginal cost.

However, the solution to this puzzle is simple. In the case of Great Britain,

²⁵It should be clear that this behavior of a vertically integrated monopolist also emerges if, in addition to unrestricted two-part access tariffs, (perfect) downstream competition is assumed. Then the mark-up from retail pricing disappears, and since there is no downstream profit to extract, the upstream firm simply sets a linear access tariff equal to the monopoly price maximizing its profit under vertical integration, i.e. $p^R(a, \theta) = a = p^I(\theta)$.

the fixed fee does generally not increase with quality. In our case, instead, the upstream firm sets the fixed fee as a function of quality—which allows her to reap all the gains from quality enhancements. Hence, despite claims to the contrary it is not the two-part tariff itself that creates the inefficiently low investment levels, but the fact that the upstream firm cannot increase the fixed component as quality increases. In contrast to recent real-world experience, the non-linear tariff can provide extremely strong volume incentives.

To sum up, this section shows that the use of non-linear access prices not only has the advantage of coping with the vertical externality. It also eliminates the mark-up distortion stemming from the industry’s vertical separation. Of course, this powerful result depends on the strong assumption that the upstream firm is able to force the downstream firms to zero profits. Aside from familiar arguments why this might not happen (for instance risk-aversion), there is also some experimental evidence casting doubt on this assumption (Roth 1995). In similar games, where two players divide some arbitrary resource (e.g. ultimatum games), players do not accept low profits, even when they are above the reservation value, and anticipating this, upstream players avoid attempting to extract all profits. If this kind of behavior is also relevant outside the laboratory, then the possibility to induce the investment incentives of an integrated firm with non-linear access prices is somewhat limited. Intermediate arrangements should be discussed, for example revenue-sharing agreements. In addition, the solution relies crucially on the (implicit) assumption that only the upstream firm can invest in quality. Without this assumption, one would have to find a solution balancing investment incentives for both firms.

4.2.2 Restricted Two-part Access Tariffs

To the extent that non-linear access pricing is allowed, it is rarely unlimited. Given a two-part tariff of the form $T(\tilde{a}) = A + \tilde{a}D(\cdot)$, regulatory restrictions might apply to the variable or the fixed fee. As long as A is unrestricted, the upstream firm will not set an arbitrarily high variable access charge \tilde{a} , even if it is free to do so. This may change if the choice of A is restricted to a sufficiently small value \bar{A} .

To analyze the effects of such a restriction, observe that under these circumstances, the optimal choice of \tilde{a} is influenced by θ , but also by the level of \bar{A} . Hence, we denote it by $\tilde{a}(\theta, \bar{A})$. We have shown that if there is no restriction on A —or if \bar{A} is high enough not to be binding, respectively—the upstream firm sets $a = 0$ to extract maximum downstream profits. Then, the incentive to invest in quality is the same as under vertical integration. On the other hand, if A is fully restricted so to $\bar{A} = 0$, the upstream firm is able to choose a linear access tariff only.²⁶ We now consider ‘intermediate’ restrictions on A .

If the restriction on the fixed premium is binding, i.e. $\pi^D = 0$, there are two effects of relaxing the constraint on A . First, assuming that the downstream price is chosen so as to satisfy the first-order condition $\Pi_p^D(p^R(\tilde{a}, \theta), \tilde{a}(\theta, \bar{A}), \bar{A}) = 0$, total differentiation of (17) yields

$$\frac{d\tilde{a}}{d\bar{A}} = -\frac{1}{D(p^R(\tilde{a}, \theta), \theta)} < 0,$$

i.e. lowering the fixed fee \bar{A} results in an increase of the variable fee \tilde{a} . The intuition for this effect is straightforward: if firm U is restricted with respect to the fixed premium it is allowed to charge, it will have to switch to variable access charges to generate access revenue. Second, total differentiation of (17) also gives

$$\frac{d\theta}{d\bar{A}} = \frac{1}{(p^R - \tilde{a})D_\theta(\cdot)} > 0,$$

i.e. lowering the fixed fee \bar{A} leads ceteris paribus to a reduction of quality. As a result, investment incentives are reduced. Therefore, restricting the fixed premium is potentially counterproductive from the point of view of generating incentives for quality.

²⁶Note that this is not the situation of vertical separation with linear access tariffs considered above, since there the linear access tariff was assumed to be exogenously set. With endogenous access tariffs, the investment incentives clearly depend on the level of the access tariff.

5 Summary and Conclusions

In this paper, we investigated the effects of different types of institutional arrangements on quality-enhancing investment by the network owner. The analysis demonstrated that incentives to invest in quality depend on the effects quality improvements have on the investor's revenue. More specifically, there is a direct effect of a quality increase which is positive, and a price-mediated effect with ambiguous sign.

Different institutional arrangements have been shown to influence these effects and thereby investment incentives. Our main results are the following:

- The difference between the revenue of a vertically separated upstream firm π^U and an integrated firm π^I is the sum of $\pi^T - \pi^U = \pi^D$ and $\pi^I - \pi^T$, where π^T denotes total industry revenue under vertical separation. The derivative of the first expression ($\pi_\theta^D > 0$) reflects the familiar vertical externality of quality enhancement on downstream revenue. The derivative of the second expression ($\partial(\pi^I - \pi^T)/\partial\theta$) reflects the mark-up effect resulting from the fact that prices are usually not the same in the separated and integrated case.
- Both the introduction of competition for the downstream market and the allowance of unrestricted two-part access tariffs eliminate the vertical externality. This result emerges because under these institutional arrangements, the downstream firm's profits are endogenously reduced to zero.
- Nevertheless, there remains an important difference between competition for the downstream market and unrestricted two-part access tariffs. Non-linear access pricing not only eliminates the vertical externality, but also the mark-up effect introduced by the vertical separation of the industry. Non-linear access pricing thus virtually replicates the situation under a vertically integrated monopoly. This is impossible if the linear access price is $a > 0$, as it is the case under competition for the downstream firm with linear access prices.

There is ample scope for further research. First, we did not consider

how investment in the downstream market affects investment incentives upstream. Second, we restricted ourselves to the analysis of a chain of monopolies. Studying imperfect downstream competition between differentiated firms (possibly owning local infrastructure monopolies) might prove to be instructive. Third, since the provision of quality depends on the auction mechanism adopted for the particular context, it would be interesting to study the provision of quality under more general forms of franchise bidding, in particular multiunit auctions for local downstream monopolies. Fourth, empirical studies could help to determine the characteristics of the demand for the final good, which in turn would inform policy decisions with respect to the institutional setting. Finally, a systematic comparison of investment incentives and actual investment in different network industries, such as telecommunications, water or electricity, could help to determine the relative importance of the various effects pointed out.

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